7. TROPICAL CYCLONE SUPPORT SUMMARY

7.1 A TROPICAL CYCLONE WIND SCALE FOR THE TROPICAL PACIFIC

LtCol Charles P. Guard
Joint Typhoon Warning Center, Guam

JTWC has developed a tropical cyclone wind scale for the tropical Pacific fashioned after the Saffir-Simpson Hurricane Scale used in the Atlantic. The scale relates tropical depression, tropical storm, typhoon, and super typhoon wind speeds to potential damage, and indicates the expected effects of coastal waves and surf. The scale considers wind effects on structures and vegetation common to the tropical Pacific region. It also considers the effects of coral reefs on storm surge and wave action. This wind scale is being passed to all tropical cyclone warning centers and to the general public throughout Micronesia, so that the population can better understand the potential impact of the wind speeds it receives in tropical cyclone warnings.

7.2 TROPICAL CYCLONE INTENSITY FORECASTING

Joint Typhoon Warning Center, Guam

Over the last two years, JTWC has placed considerable emphasis on improving tropical cyclone intensity forecasts. The results have been very encouraging. Techniques are based on: (1) the work of Mundell (1990), which relates the potential for rapid or explosive deepening to current intensity at a specific latitude, other location criteria, and month; (2) locally developed rules-of-thumb that consider the relationship of a tropical cyclone to multiple outflow channel mechanisms, such as a combination of mid-

latitude troughs, TUTT-cells, and upper-tropospheric channels to the subtropical jet stream; (3) conditional climatology applications that allow specific stratification of current cyclone characteristics to determine the most likely average, maximum, and minimum intensity values at various forecast periods; and, (4) meteorological satellite interpretation of conditions favorable for intensification or weakening, such as vertical shear, TUTT-cell movements, and pixel-counting techniques by Capt Shoemaker as indicated in section 7.12. The Naval Research Laboratory at Monterey, California will adapt the intensity forecast model used in the Atlantic to the Pacific to help JTWC assess its skill.

7.3 HYBRID FORECAST AIDS

Capt Dan B. Mundell, USAF
Joint Typhoon Warning Center, Guam

"Hybrid" forecast aids are defined as a blend of two or more existing forecast aids, and may provide better guidance for the tropical cyclone forecaster than any of the single aids upon which the hybrid is based. Since it is often difficult to determine the "best" aid for each warning, hybrids help reduce the chances for very large errors in difficult forecast situations by weighting the forecast guidance toward the (historically) best-performing aids.

Verification statistics of objective techniques from 1986 to 1991 were used to determine the best- and worst-performing aids in the western North Pacific over a six-year period. A set of regression equations was developed, weighted more heavily toward techniques with the lowest overall forecast errors.

The first hybrid, called BLND, weights nine separate forecast aids (OTCM, CSUM,

FBAM, CLIP, HPAC, TOTL, RECR, CLIM and XTRP) relative to their average errors at 24-, 48- and 72-hours. The second, termed WGTD, is biased toward the dynamic aids OTCM, CSUM and FBAM, which are weighted twice as much as the climatological aids CLIP, HPAC, TOTL and RECR.

7.4 EXTENSION OF CONDITIONAL CLIMATOLOGY DATA BASE

Capt Dan B. Mundell, USAF
Joint Typhoon Warning Center, Guam

The Joint Typhoon Warning Center's conditional climatology data base for the western North Pacific, which is used to identify climatological analogs and derive long-range intensity forecasts, has been updated to include best track positions prior to the issuance of the first warning and extratropical or dissipating cyclone positions after the final warning. This allows JTWC forecasters to pinpoint suitable analogs and determine the most likely rate of intensity change earlier than previously possible.

In addition, best track intensities have been adjusted to agree more closely with dropsonde measurements of minimum sea-level pressure, when available. This adjustment provides greater consistency within the data set because the Atkinson-Holliday (1977) wind and pressure relationship was applied equally as a basis for estimates of maximum sustained winds.

7.5 LATITUDINAL RELATIONSHIP OF TROPICAL CYCLONE PEAK INTENSITY AND PEAKING DAY

Capt Dan B. Mundell, USAF
Joint Typhoon Warning Center, Guam

Two of the most difficult aspects of tropical cyclone intensity forecasting are the peak intensity and the point in time when the anticipated peak intensity will be reached. A high correlation exists between the latitude of initial upgrade to tropical storm and peak intensity in the western North Pacific Ocean (Figure 7-1A), and between the latitude of initial upgrade to typhoon and the peak intensity attained by the cyclone (Figure 7-1B). Generally, low-latitude disturbances, which intensify to tropical storm intensity outside the South China Sea basin, are more likely to become very intense typhoons because they spend a longer time in a favorable low shear and warm sea-surface temperature environment south of the subtropical ridge axis (Figure 7-2).

Application of this latitudinal relationship to future warnings is expected to reduce JTWC's longer range intensity forecast errors (Refer to section 7.2).

7.6 PROTOTYPE AUTOMATIC TROPICAL CYCLONE HANDBOOK (PATCH)

C.R. Sampson, Lt R.A. Jeffries
and Lt S. Aslan
Naval Research Laboratory
Monterey, California

Development of the expert system continues. PATCH is an expert system designed to provide tropical cyclone forecast guidance based on synoptic data, pattern recognition, thumb rules and research results. An automated procedure has been developed to provide guidance for tropical cyclone motion in the western North Pacific. This procedure includes expertise on synoptic patterns, steering, island effects and acceleration after recurvature. In the future, the system will include expertise regarding objective technique performance, tropical cyclone formation, binary interaction and tropical cyclone intensity forecasting.
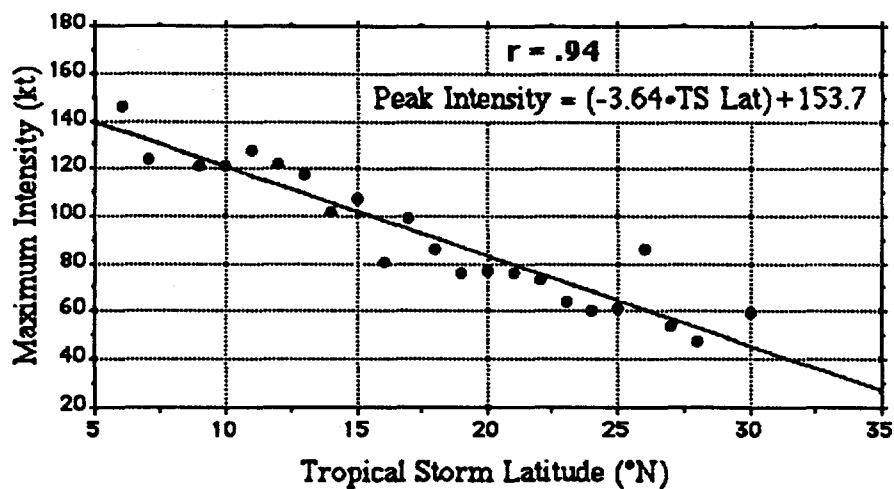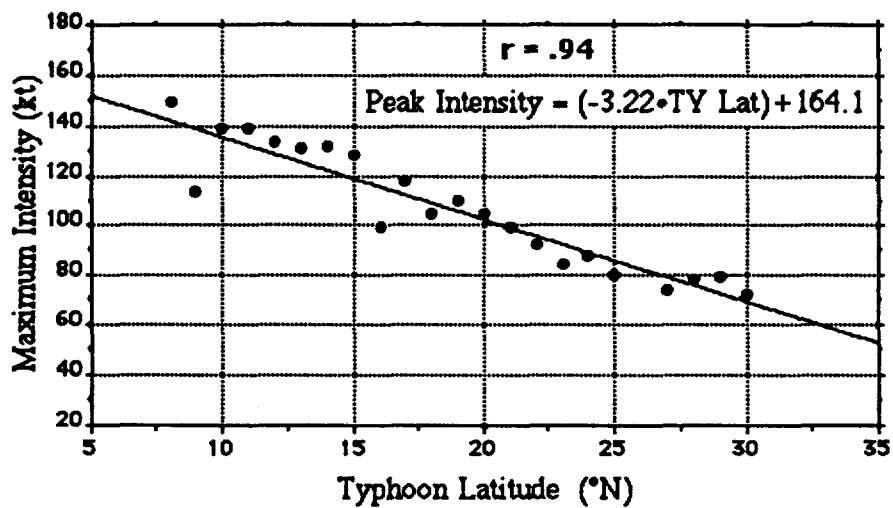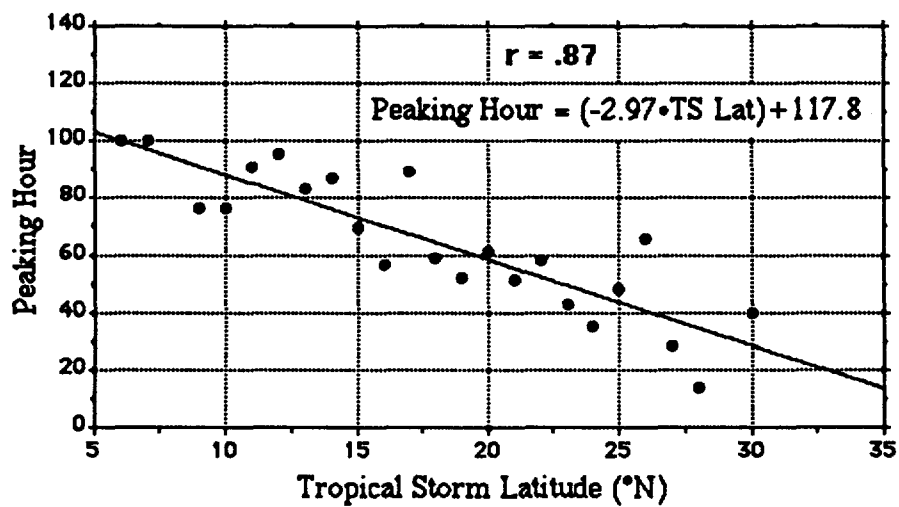
Figure 7-1A

Figure 7-1B

Figure 7-2

7.7 AUTOMATED TROPICAL CYCLONE FORECASTING SYSTEM (ATCF) UPGRADE

D.M. Roesser, R.J. Miller and C.R. Sampson
Naval Research Laboratory (NRL)
Monterey, California

The ATCF has been operational at JTWC since 1988. The system runs on an IBM-AT compatible machine using the MS-DOS operating system. Currently NRL is adapting the ATCF to a UNIX environment. UNIX advantages include multi-tasking, unlimited memory, and portability. The new ATCF will use industry standard X-Windows/Motif for window management.

7.8 JTWC92 MODEL

C.J. Neumann and T.L. Tsui
Naval Research Laboratory
Monterey, California

JTWC92 is a statistical-dynamical model for tropical cyclone track forecasting. It is a modification of the NHC90 model which has shown significant skill in the Atlantic. JTWC92 is currently undergoing operational testing and evaluation and is scheduled to become operational by June 1992. Preliminary results show that forecast errors for 1990 data (125 cases) are 81, 157 and 285 nm for 24, 48, and 72 hours respectively. These results were obtained using operational tropical cyclone positions for model input and best track positions for forecast track verification.

7.9 NEURAL NETWORK APPLIED TO 24-HOUR MOTION FORECAST

J.H. Chu, R.L. Bankert, S.K. Sengupta, P. Rabindra, R.J. Miller, J.M. Shelton and C.R. Sampson
Naval Research Laboratory
Monterey, California

A statistical model for western North Pacific 24-hour tropical cyclone motion forecasts has been developed and tested. The potential predictors of model output are the tropospheric deep-layer-mean height fields and the past 12-hour cyclone motion vectors based on data or derived from data during the period from 1974 to 1989. A feature selection procedure was adopted for ranking these potential predictors according to their significance in discriminating the output classes. Top features based on this ranking are used for training of a probabilistic neural network. The trained neural network model was used to test its forecast ability in 1989. The overall skill score of the statistical model was comparable to that of JTWC forecasts.

7.10 TROPICAL CYCLONE FORE-CASTER'S REFERENCE GUIDE

Lt R.A. Jeffries, R.J. Miller, J.H. Chu and C.R. Sampson
Naval Research Laboratory
Monterey, California

Development of a Tropical Cyclone Forecaster's Reference Guide continues. The reference guide will contain a section covering general tropical meteorology, formation, motion, structure, and dissipation of tropical cyclones. Satellite and numerical model case studies and descriptions of forecast aids will

also be included. When each section of the reference guide is completed, it is converted to a computer-based information system stored on CD-ROM media.

7.11 NOGAPS TROPICAL CYCLONE FORECAST PERFORMANCE

J.S. Goerss and Lt R.A. Jeffries
Naval Research Laboratory
Monterey, California

Synthetic observations generated from the reported positions and intensities of tropical cyclones have been assimilated into NOGAPS since June 1990. In June 1991, these observations were made available to the 72- and 120-hour forecast runs of NOGAPS as well as to each analysis of the NOGAPS data assimilation cycle. A complete evaluation of NOGAPS tropical cyclone forecast performance in the western North Pacific was performed for 1991.

7.12 TECHNIQUE DEVELOPMENT

Capt Daniel N. Shoemaker, USAF
Detachment 1, 633 Operations Support
Squadron

Pixel-counting techniques and insights by Zehr (1987, 1991) are being applied to satellite infrared signatures of tropical cyclones to improve tropical cyclone analysis and forecasting. Although the initial sample (11 tropical cyclones) is small, preliminary thumb rules have been developed and their validity will continue be tested as the data base is expanded.

7.13 ARTICLE FOR *WEATHER AND FORECASTING*

LtCol C.P. Guard, LtCmdr L.E. Carr, F.H.Wells,
Lt R.A. Jeffries, LtCmdr N.D. Gural
and Lt D.K.Edson
Joint Typhoon Warning Center

The survey article, Joint Typhoon Warning Center and the Challenges of Multibasin Tropical Cyclone Forecasting, was written and submitted to the American Meteorological Society for publication in the Special Military Edition of *Weather and Forecasting*. The paper discusses the challenges to the center as a result of its vast multibasin area of responsibility, the products the center produces, its warning philosophy, observational networks, analysis and forecasting schemes, and the military aspects of the operation. Also briefly discussed are JTWC's colorful history, the joint Navy-Air Force Operations Evaluation to assess the impact of the loss of aircraft reconnaissance, and the ONR's Tropical Cyclone Motion-90 Experiment. Finally, the paper takes a quick look at JTWC's post analysis program, training, qualification, and certification programs; and technique development to improve tropical cyclone analysis and forecasting.

7.14 CHARACTERISTICS OF TROPICAL CYCLONES AFFECTING THE PHILIPPINE ISLANDS

Capt Daniel N. Shoemaker, USAF
Detachment 1, 633 Operations Support
Squadron

This study updates two earlier papers, Brand and Blelloch (1972) and Sikora (1976),

225

on tropical cyclones affecting the Philippine Islands. Forty-five years of data for tropical cyclones near the Philippine Islands were examined to determine tropical cyclone intensity change, track change, occurrence climatology, and various other parameters. From a climatological perspective, the study allows the typhoon forecaster to more accurately anticipate changes in tropical cyclone intensity and motion. This study was published as NOCC/JTWC Technical Note 91-1 and is available from NOCC/JTWC, COMNAVMAR, PSC 489, Box 12, FPO AP 96540-0051.

7.15. TROPICAL CYCLONES AFFECTING GUAM (1671-1990)

Frank H. Wells, Editor
Joint Typhoon Warning Center, Guam

A climatology of tropical cyclones passing near Guam was presented for the period 1945-1990. A review of all typhoons affecting Guam was taken back to 1800, and some noteworthy typhoons of the 1600's were included. The survey encompassed the frequency, behavior, meteorological effects and descriptive chronicles of Guam tropical cyclones. The emphasis was on the period following World War II. This survey was published as NOCC/JTWC Technical Note 91-2 and is available from NOCC/JTWC, COMNAVMAR, PSC 489, Box 12, FPO AP 96540-0051.

7.16 A COST-BENEFIT ANALYSIS OF THE USPACOM TROPICAL CYCLONE WARNING SYSTEM

LtCol Charles P. Guard
Joint Typhoon Warning Center, Guam

A preliminary cost-benefit analysis was conducted with regards to the USPACOM Tropical Cyclone Warning System and indicated

annual savings realized from the warning service provided by JTWC to be in excess of $10 million per year. The cost of JTWC support was not presented in the preliminary analysis. These results were presented at the 1992 Annual Tropical Cyclone Conference where the USCINCPAC representative requested that a final study be completed by 1 July 1992 and submitted to Environmental Group USPACOM.

7.17 CONTRIBUTIONS OF THE OFFICE OF NAVAL RESEARCH PhD CHAIR AT THE UNIVERSITY OF GUAM

Dr. Mark A. Lander
University of Guam

In late June of 1991, Dr. Mark A. Lander accepted a newly created Research Associate position at the University of Guam supported by the Office of Naval Research (ONR). His research efforts include new and continuing studies of tropical cyclone motion.

Much of the behavior of tropical cyclone motion can be understood in the context of an interaction of the cyclone with other vortices in the cyclone's environment. When two or more tropical cyclones are within range to interact, the position errors of the forecasts of the JTWC increase. Lander and Holland (1992) extend the work of Dong and Neumann (1983) on the properties of the motion of binary tropical cyclones and develop a generalized model of their specific behavior. Companion papers concerning the theoretical description and numerical simulation of interacting vortices, by Holland with other scientists at the Australian Bureau of Meteorology Research Center, have been submitted along with Lander and Holland (1992) to the *Quarterly Journal of the Royal Meteorological Society*.

In another paper, Holland and Lander (1992), convincing evidence is presented to

show that some of the meandering nature of tropical cyclone tracks can be attributed to interactions between tropical cyclones and mesoscale cloud clusters within the cyclone's outer circulation. This paper has been accepted for publication in the *Journal of the Atmospheric Sciences.*

A close scrutiny of the tropical cyclones occurring in the western North Pacific during 1991 has resulted in a new series of research papers concerning the influence of the monsoon trough on the structure and motion of tropical cyclones. The northward-displaced, self-sustaining, solitary monsoon gyre , the first of a planned series of papers expected to be written concerning the monsoon trough and its affects on the motion and structure of tropical cyclones, is being submitted to *Weather and Forecasting.*

The midget tropical cyclone has been written in collaboration with LtCol Guard and is being submitted to *Monthly Weather Review.*

The close proximity of the Joint Typhoon Warning Center (JTWC) to the University of Guam provides a special opportunity to use the assets of the JTWC to monitor tropical cyclones in real time and capture unique and often perishable data on interesting phenomena which are important in research efforts. By virtue of its location in the world's most prolific "Typhoon Alley", Guam (the island itself, the University of Guam, and the JTWC) provides the tropical research meteorologist a unique natural laboratory to study and find answers to existing problems in tropical meteorology.

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